Development of GFDL's next generation IPCC-class model

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for the Model Development Team

Geophysical Fluid Dynamics Laboratory

Model development diversified after AR4

CM2 (our AR4 model) evolved in numerous directions in past 7 years:

ESM2M, ESM2G:	carbon cycle
CM2.1 + data assimilation:	seasonal-decadal initialized forecasts
CM3:	aerosols, indirect effect, chemistry
HiRAM:	hi res atmosphere, tropical storms
CM2.5	hi res coupled model

All of these models contributed to AR5

Need to combine strengths of GFDL's multiple AR5 modeling streams into new trunk model

GFDL formed a new Model Development Team (MDT) in 2013

Goal of the MDT

In the 2013-2016 time frame, design and develop GFDL's best attempt at a climate model suitable for

a) projection of climate change up to several hundred years into the future,
b) attribution of climate change over the past century,
c) prediction on seasonal to decadal time scales

keeping in mind the needs for improved regional climate information and assessments of diverse climate impacts.

The model will be capable of running from emissions in regard to both the carbon cycle and aerosols.

New model configurations are being tested

Target horizontal resolution for CM4/ESM4:
50 km atmosphere + ¼ degree ocean (MOM6)

Determined by

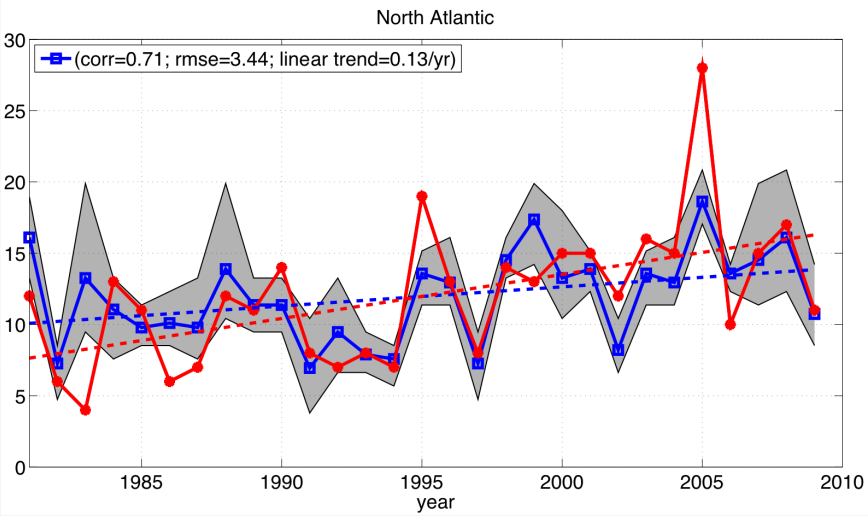
1) Lab's experience regarding resources needed to develop and utilize a model for centennial-scale climate projections:
at least 3-5 years/day throughput on no more than 1/8 of computational resource

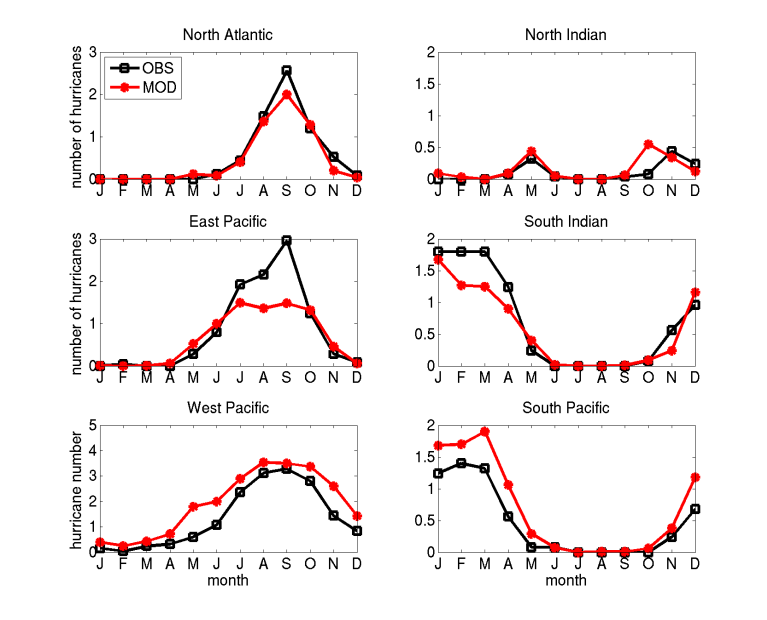
2) the GAEA computational resource

Increases in hardware resources and significant software development would allow us to redefine this trunk model towards higher resolution and/or greater comprehensiveness, e.g. full eddy-resolving ocean resolution; more complete stratosphere/troposphere chemistry module

Our AR5 models have redefined our metrics

HiRAM Atmosphere/land 50 km model
S-J- Lin, Ming Zhao





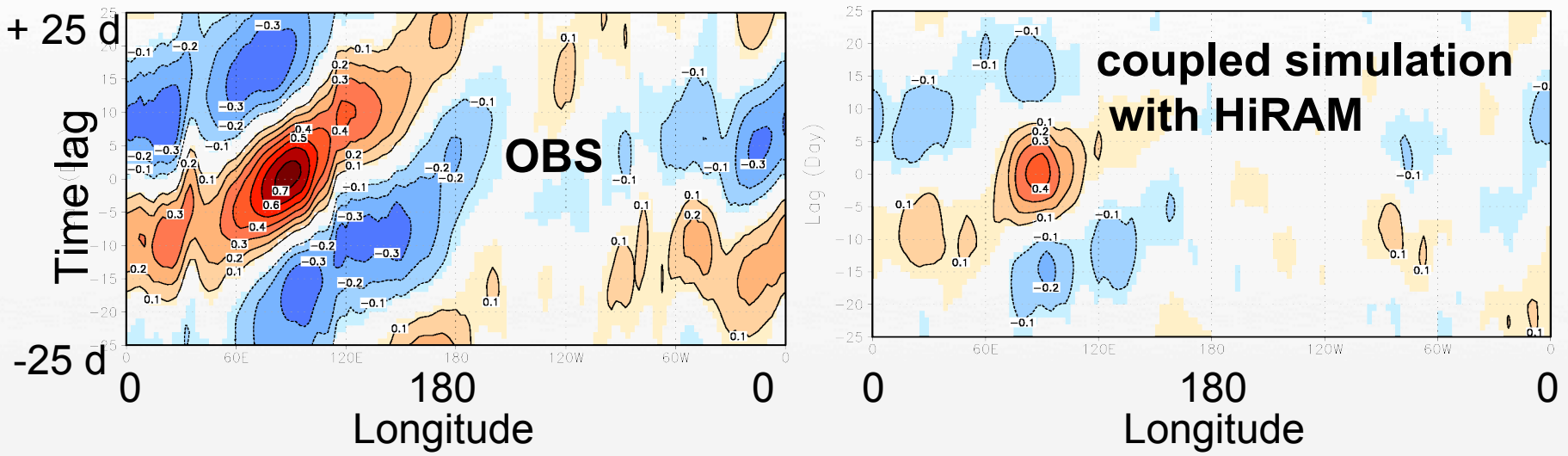
tropical cyclones in North Atlantic over last 30 years

Seasonal cycle of hurricanes in different ocean basins

Example: Hurricane frequency

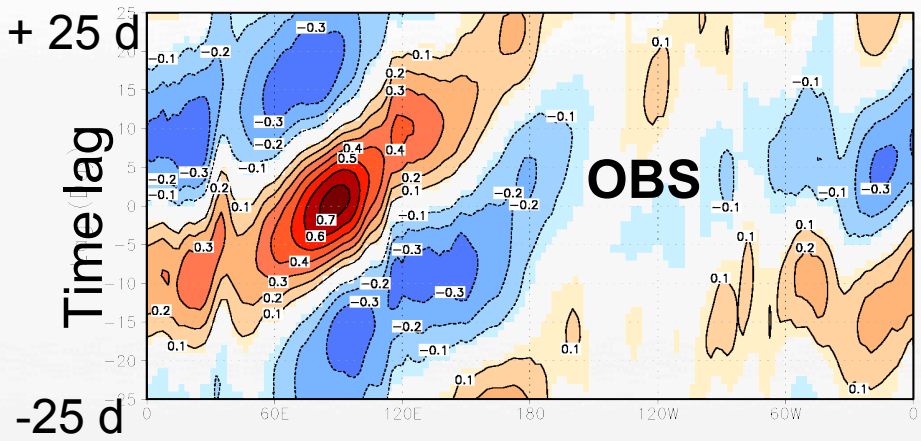
Example of important metric: Madden-Julian Oscillation(MJO)

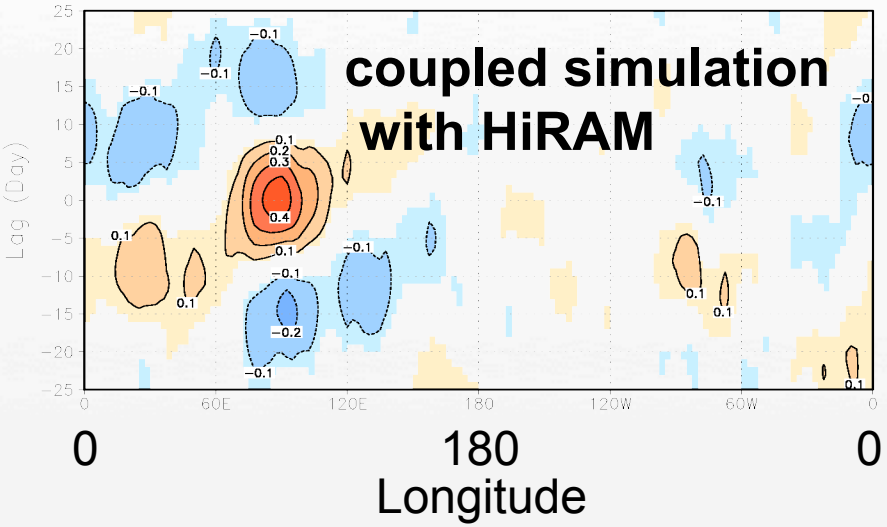
Equatorial outgoing longwave radiation; correlation(time lag, longitude)
(US CLIVAR MJO standard diagnostic)

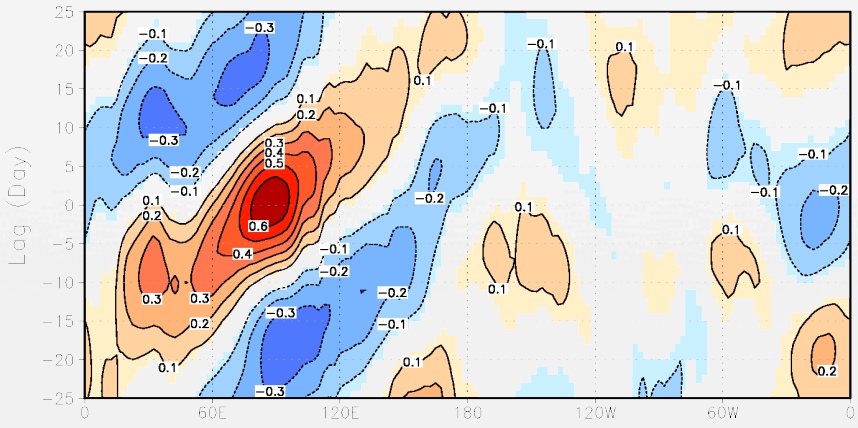


Recent progress: MJO in new atmospheric configuration

Equatorial outgoing longwave radiation; correlation(time lag, longitude)
(US CLIVAR MJO standard diagnostic)

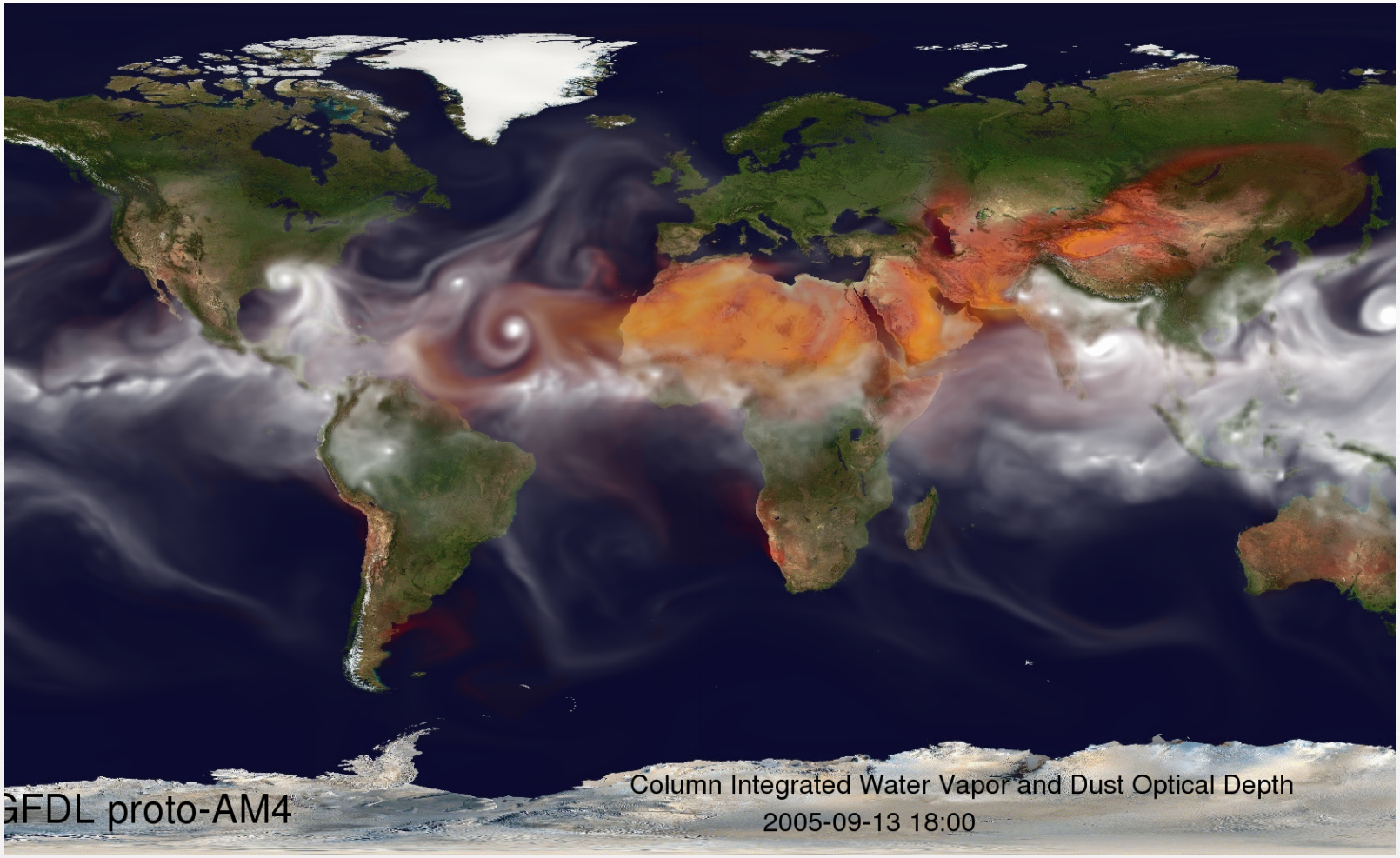






coupled simulation with alternative convection scheme (Ming Zhao)

Dust + hurricanes in proto-AM4



Paul Ginoux

A few examples of challenges facing the MDT

Oceanic mesoscale eddies

Can we make a ¼ degree model look like an eddy-resolving model?

Aerosol/cloud interactions

How do we best combine bottom-up (process-oriented) perspective and top-down constraints provided by 20th century observations?

Atmospheric boundary layer/low cloud feedbacks

Are we in a position to incorporate a dramatically new type of boundary layer/shallow convection module similar to CLUBB?

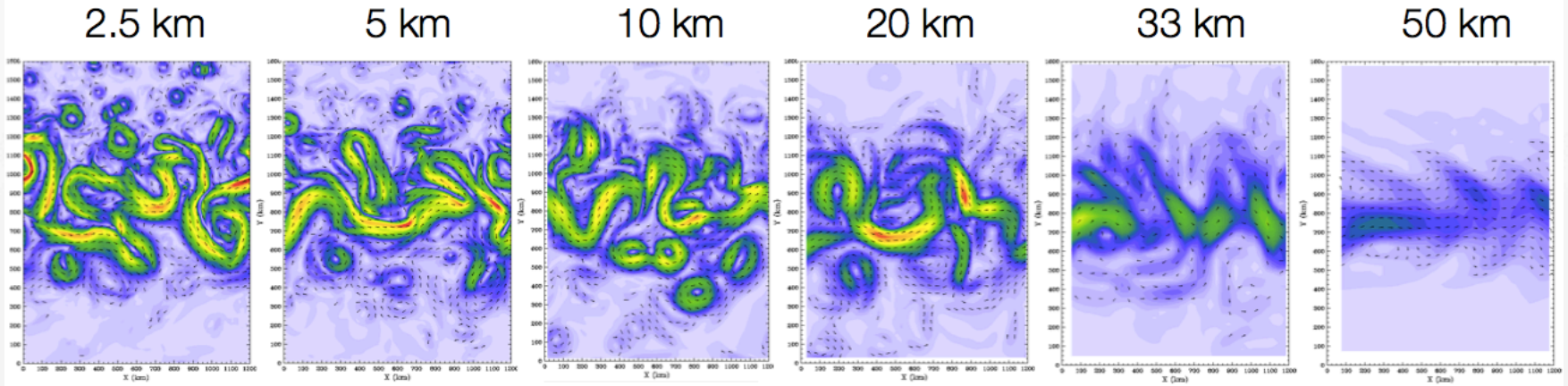
Software

Can we find more concurrency to improve wall clock performance so that we can increase complexity/resolution relevant to MDT goals

25km ocean model is in “eddy-permitting” regime

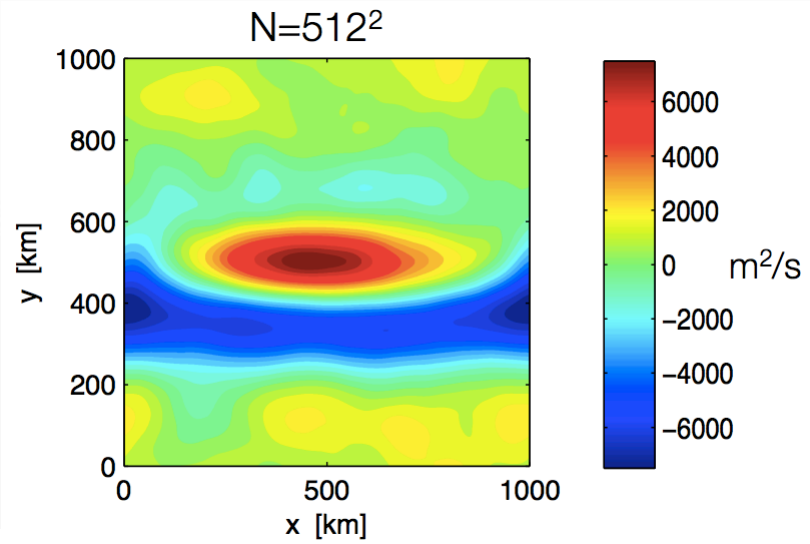
Series of idealized simulations of zonal jet in 1200 km x 1600 km zonally re-entrant domain (from Hallberg 2013)

Snapshots of upper ocean velocity at various resolutions ($k_d^{-1} \approx 30$km):

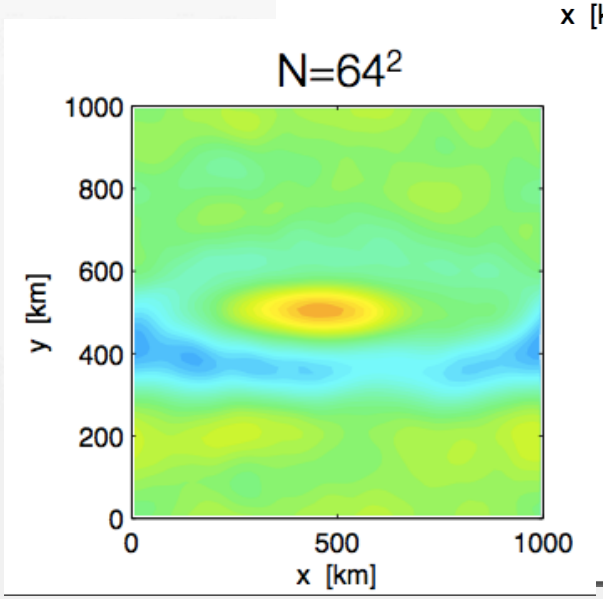


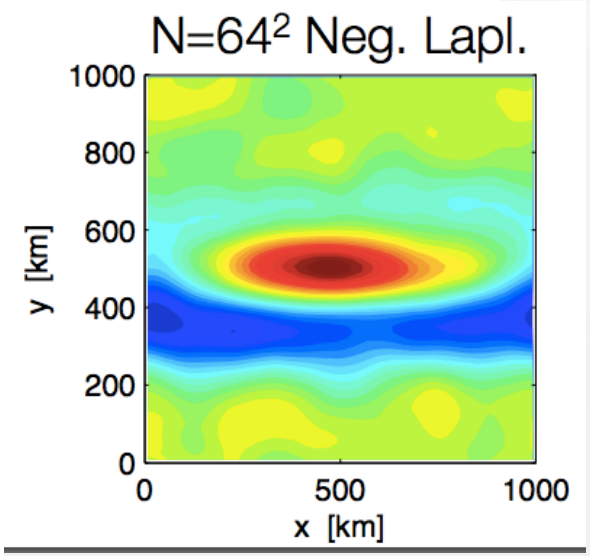
Learning how to work in eddy-permitting regime: ie, simple “backscatter” scheme

Mean flow in simple turbulent ocean model



Malte Jansen, 2014





Timeline

Atmosphere/Land development in AMIP mode
MOM6 code development
Exploratory atmos-ocean coupling

Continued physical model development
ESM: Carbon cycle, ocean biogeo, etc
Alternative resolutions

Continued Atmos/Land development in coupled mode
Alternative MOM6 configurations